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Operational Aspects of the 16 April Tornadoes and the 27-28 April 2011 Tornado Outbreak in the WFO LWX Forecast Area

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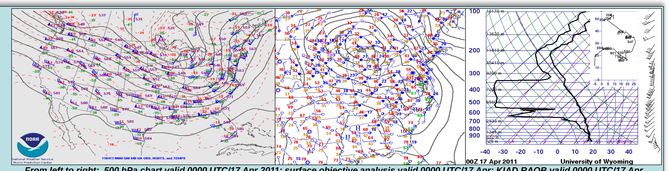
INTRODUCTION

The National Weather Service (NWS) Baltimore/Washington Forecast Office in Sterling, VA (WFO LWX) experienced two significant tornadic episodes during April 2011, which contributed to a near-record tornado season in the WFO LWX forecast area. During the 27-28 April tornado outbreak, portions of the WFO LWX forecast area were under a Tornado Watch for nearly 24 hours (an unprecedented length of time for this part of the country), with at least 19 tornadoes of EF-0 to EF-2 intensity during a 17-hour period.

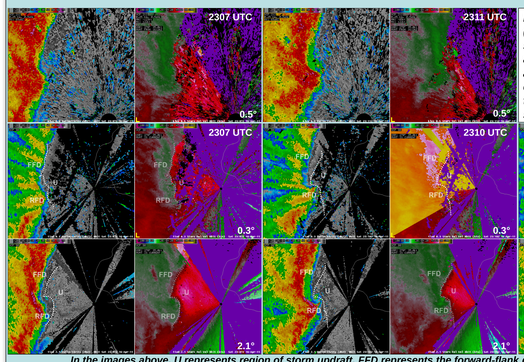
The WFO LWX forecast area is unique owing to the presence of four Federal Aviation Administration Terminal Doppler Weather Radars (TDWRs) in addition to the NWS Weather Surveillance Radar-88 Doppler (WSR-88D). The four TDWRs offer warning forecasters one-minute updates of low-level reflectivity and velocity data in addition to the four-minute volume scan updates provided by the WSR-88D. Owing to the comparatively higher temporal and spatial resolution of the TDWR data, low-level reflectivity and velocity features are detected and tracked far more readily than in WSR-88D data. In the events below, the utility of these data are shown for both warning decision-making and storm event follow-up and surveying.

16 APRIL TORNADOES

- Negatively-tilted 500 hPa shortwave trough over Ohio
- Jet maximum at 500 hPA over the Mid-Atlantic region
- Surface low pressure over Michigan
- Negatively-tilted surface trough axis across the Mid-Atlantic region
- Moist boundary layer east of Blue Ridge with dewpoints in the lower 60s
- Strong winds and clockwise hodograph through 600 hPa
- Nearly straight-line hodograph in lowest 700m



From left to right: 500 hPa chart valid 0000 UTC/17 Apr 2011; surface objective analysis valid 0000 UTC/17 Apr; KIAD RAOB valid 0000 UTC/17 Apr.

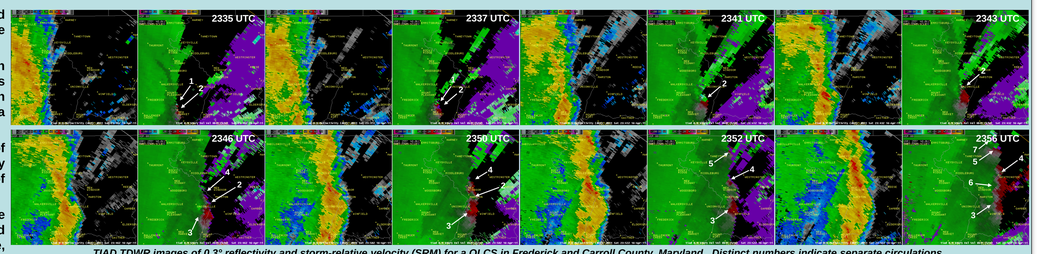


Reflectivity and storm-relative velocity (SRM) images of a line-embedded tornadic supercell. Top panes are from KLWX (WSR-88D) at 0.5° elevation; bottom four panels are from TIAD (TDWR) at 0.3° and 2.1° elevation. TIAD was located 2.0-5.0 nm from the tornadic circulation. The 0.3° elevation slice from TIAD sampled below cloud base.

- Supercell embedded in convective line
- Produced 65-75 mph EF-0 tornado
- TDWR TIAD sampled storm at close range with one-minute 0.3° temporal resolution
- TIAD 0.3° elevation Z and V sampled the sub-cloud circulation
- Wrapping rain at multiple scales noted in hook echo
- Structure missed almost entirely by KLWX WSR-88D radar owing to poor temporal resolution
- Tornado ends when mesocyclone is undercut by FFD

In the images above, U represents region of storm updraft, FFD represents the forward-flank downdraft and RFD represents the rear-flank downdraft. Dotted lines represent gust fronts.

- Mesovortices formed along leading edge outflow of QLCS
- At least seven distinct circulations were detected in TIAD velocity data from 2335-2358 UTC
- Tornadic damage of EF0-EF1 intensity occurred with five of these circulations
- Damage tracks were discontinuous and scalloped in shape, suggesting a cyclic process (see below for more details of the damage paths)



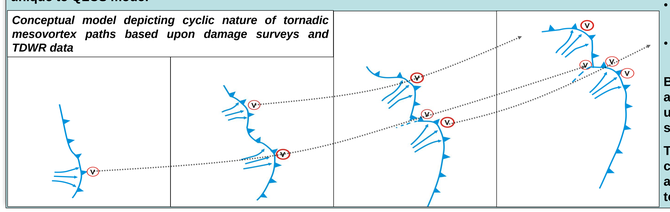
TIAD TDWR images of 0.3° reflectivity and storm-relative velocity (SRM) for a QLCS in Frederick and Carroll County, Maryland. Distinct numbers indicate separate circulations.

•Several funnel clouds (that then became rain-wrapped) were reported in association with these tornadoes

•Owing to its poorer temporal resolution, not all of the independent circulations could be identified in data from KLWX WSR-88D

Recent surveys of tornadoes generated in QLCSs revealed interesting details that seem to be relatively unique to QLCS mode:

Conceptual model depicting cyclic nature of tornadic mesovortex paths based upon damage surveys and TDWR data

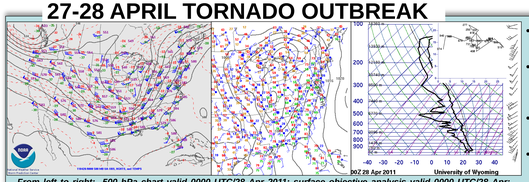


- Often short, scalloped, cyclic damage paths
- Such paths are associated with several, independent TDWR mesovortices that often appear as one circulation in WSR-88D data
- Often embedded in swaths of inconclusive or straight-line wind damage associated with surging gust front (e.g. Atkins et al. 2005)

Based on WSR-88D data alone, these damage paths might be classified erroneously as a single tornado unless a very careful inspection of the damage paths is undertaken. This can prove challenging when several tracks must be surveyed in a short time.

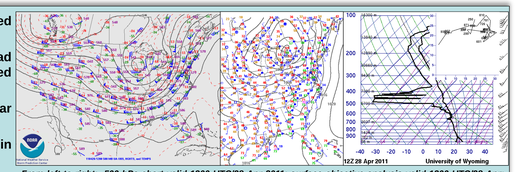
These tornadic damage paths necessarily must be associated with separate circulations owing to the non-mesocyclonic nature of their development (e.g. Atkins and St. Laurent 2009). So it is logical that these would be classified as individual tornadoes akin to cyclic tornadogenesis in supercell thunderstorms.

27-28 APRIL TORNADO OUTBREAK



From left to right: 500 hPa chart valid 0000 UTC/28 Apr 2011; surface objective analysis valid 0000 UTC/28 Apr; KIAD RAOB valid 0000 UTC/28 Apr.

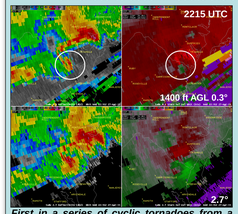
- Deep 500 hPa closed low over Minnesota
- Lead impulses ahead of closed low provided strong flow
- High low-level shear owing to low-level jet
- Broad warm sector in the Atlantic states
- Dewpoints in upper 60s



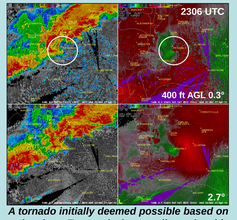
From left to right: 500 hPa chart valid 1200 UTC/28 Apr 2011; surface objective analysis valid 1200 UTC/28 Apr; KIAD RAOB valid 1200 UTC/28 Apr.

Afternoon tornadoes

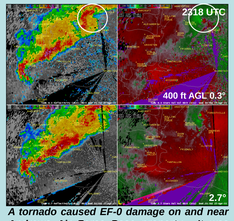
Severe thunderstorms began to impact the WFO LWX forecast area during mid-afternoon on 27 April. The afternoon portion of this event had been anticipated four days in advance, so staffing levels were enhanced to accommodate the expected weather demands. A selection from the four afternoon tornadoes is shown below. Images show reflectivity (left, in dBZ) and storm-relative velocity (right, in kt).



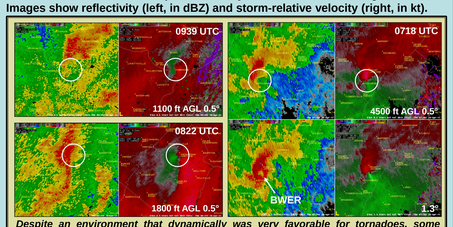
First in a series of cyclic tornadoes from a supercell thunderstorm. The brief EF-0 tornado near Quantico was seen by spotters and the Quantico Base weather observer. Hail up to 1.50 in diameter was observed



A tornado initially deemed possible based on radar data. Targeted phone calls under this circulation led to a small airport, where EF-0 damage was sustained by several small aircraft



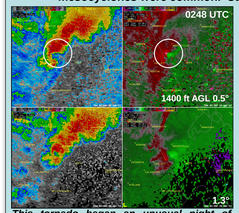
A tornado caused EF-0 damage on and near Andrews Air Force Base property. It was observed from the World Weather Building in Camp Spring, MD, and was documented from close proximity in online video



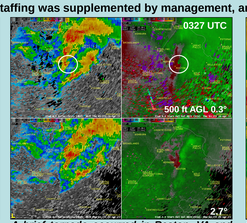
Despite an environment that dynamically was very favorable for tornadoes, some storms (like those above) with radar presentations similar to, or better than, confirmed tornadic storms did not produce tornadoes. This similarity made warning operations and subsequent survey planning challenging and necessitated targeted phone calls to seek damage reports

Overnight tornadoes

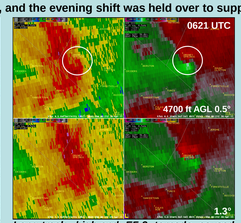
During what is climatologically an unfavorable time for tornadoes in the WFO LWX forecast area, nine tornadoes occurred, including one strong, long-track tornado. Signatures of very strong updrafts and mesocyclones were common. Staffing was supplemented by management, and the evening shift was held over to support operations. A selection from the nine tornadoes is shown below.



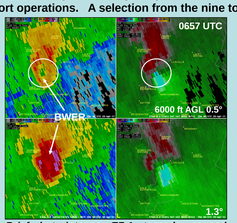
This tornado began an unusual night of damaging tornadoes, enduring 15 min as it caused EF-1 damage near Nokesville, VA



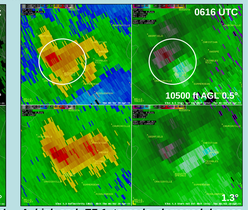
A brief tornado occurred in Reston, VA and caused high-end EF-0 damage primarily to trees



Long-track, high-end EF-2 tornado caused significant damage along a 30+ mile stretch of Shenandoah County, VA. Remarkably, no injuries were sustained despite a trailer home being destroyed completely



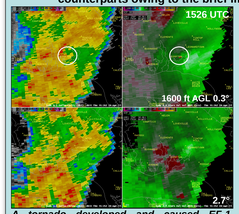
Brief but intense EF-1 tornado caused damage primarily to trees. A bounded weak-echo region is seen in reflectivity just prior to tornadogenesis



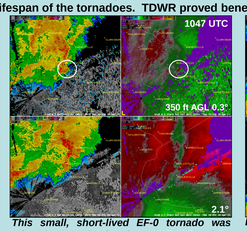
A high-end EF-1 tornado damaged homes and trees and destroyed outbuildings. Lowest elevation scan is 10.5 kft AGL! Distance from the radar and partial beam blockage add to the challenge

Morning tornadoes

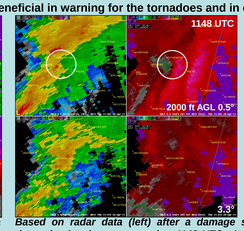
Six additional short-lived tornadoes occurred in Maryland after sunrise on 28 April. Damage tracks were found to be much narrower, and radar signatures were much more subtle than their overnight counterparts owing to the brief lifespan of the tornadoes. TDWR proved beneficial in warning for the tornadoes and in determining subsequently where to search for damage. A selection is shown below.



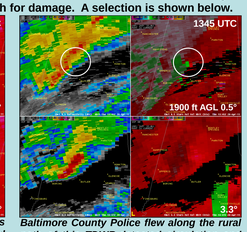
A tornado developed and caused EF-1 damage near Breton Bay, MD as a storm came ashore from the Tidal Potomac River



This small, short-lived EF-0 tornado was missed completely in WSR-88D data. Damage was found to trees and fences



Based on radar data (left) after a damage survey was completed, an EF-0 tornado was determined to have occurred at 1148 UTC. It was found later that the report of damage had been made to the 911 Center at 1143 UTC. The tornado actually occurred at 1136 UTC (right)



Baltimore County Police flew along the rural path of this TDWR-detected circulation and found a path consisting of tree damage that otherwise would have been missed

CONCLUSIONS

- The 16 April and 27-28 April 2011 environments were quite favorable for tornadoes in the WFO LWX forecast area
- QLCS tornadoes on 16 April (and in general) tended to follow short, scalloped paths generated by multiple, shorter-lived circulations instead of a single, continuous circulation
- The strongest, longest-lived and most destructive tornadoes on 28 April occurred at a climatologically unfavorable time of day
- Use of one-minute resolution data from Terminal Doppler Weather Radars proved invaluable in diagnosing developing tornadic circulations on both days, especially between WSR-88D scans
- With higher spatial and temporal resolution, TDWR data provided effective means to focus damage searches via targeted phone calls and surveys
- Damage in rural areas often goes unreported unless a survey is conducted or targeted phone calls are made
- Some circulations did not produce tornadoes despite presenting signatures similar to (or better than) confirmed tornadic storms; warning decisions proved challenging in such a favorable environment
- Delayed reports arrived at WFO LWX even months after the event; one report arrived three months late; another, seven months late
- In outbreak-type events, processing of reports can be an all-consuming effort; two or more dedicated staff may be needed

**References available upon request*